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AUTHOR Tuan, Hsiao-lin; And Others
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ABSTRACT

The goals of secondary preservice science teacher education are to prepare future science teachers with competency in both science content knowledge and science teaching ability. The study reported in this paper investigated the development of pedagogical content knowledge of three preservice chemistry teachers in Taiwan during one year of a practicum course. Qualitative ways of collecting data included semi-structured interviews before and after each teaching experience, classroom observation, and assignment collection. Interview questions addressed subjects' views of chemistry and the topics they taught, ways of transmitting content knowledge to students, and their views on general pedagogy. Results indicate that after experiencing one year of the practicum course preservice chemistry teachers' views of chemistry became simplified but their knowledge of teaching became more complicated and focused more on students' characteristics and learning styles than before. During the year the preservice teachers gained an awareness of the importance of pedagogical content knowledge in improving their future science teaching. Factors influencing preservice chemistry teachers' pedagogical content knowledge development were their preference, reflection ability, and deprived teaching repertoire. Suggestions for science teacher education are discussed. Contains 19 references. (Author/JRH)

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A CASE STUDY OF PRE-SERVICE CHEMISTRY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE DEVELOPMENT

ED 387 335

Hsiao-lin Tuan

Bih-Yun Jeng

Lyee-Juan Whang

Rong-Chen Kaou

National Changhua University of Education
Changhua Taiwan R.O.C.

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Abstract

This study investigated the development of pedagogical content knowledge from three pre-service chemistry teachers during one year of practicum course. Shulman's(1986), Cochran et al (1993), and Lederman, et al (1994) views of pedagogical content knowledge were applied as research framework for investigation. Qualitative ways in collecting data included semi-structured interviews before and after each teaching experience; classroom observation; and assignment collection. Themes of practicum course included twice 20 minutes micro-teaching experience and one month field-based experience. Interviews addressed on subjects' views of chemistry and the topics they taught, ways in transmitting these content knowledge to students, and their views of general pedagogy.

After experiencing one year of practicum course, pre-service chemistry teachers' view of chemistry became simplified. On the contrary, their knowledge of teaching became more complicated, and focused more on students' characteristic and learning style than before. They linked content and pedagogy together at the end of year. Most of their pedagogical content knowledge included terminology explanation, and analogies using etc. Although pre-service chemistry teachers' pedagogical content knowledge do not change much. Toward the end of study, the pre-service chemistry teachers' gained the awareness of the importance of pedagogical content knowledge in improving their future science teaching. Factors influenced these pre-service chemistry teachers' pedagogical content knowledge development were their preference, reflection ability, and deprived teaching repertoire. Suggestions for future science teacher education were addressed in this study.

Introduction

The goals of secondary pre-service science teacher education are to prepare future science teachers with competency in both science content knowledge and science teaching ability. In order to cultivate future teachers with these competence, science teacher education programs provide with two branches of courses -- subject-matter courses, and educational courses. Many of pre-service will take most of the content courses, and few courses on education then they can become teachers. The general beliefs held by this kind of design are that after taking these courses, the pre-service teachers would automatically integrate these two separate knowledge -- pedagogy and subject matter, and fluently implement them into classroom teaching. However, during past years, science educators(Lederman, Gess-Newsome, Latz,1994; Gess-Newsome & . Lederman, 1992; Lederman & Latz, 1993; Hoz, Tomer, & Tamir, 1990; Hashweh, 1986) started to address the importance of science teachers' (both in-service and pre-service) content and pedagogy knowledge, and how these knowledge influenced each other on their classroom teaching. These researchers also tried to reveal the mystery of whether separately taking courses on content and pedagogy could automatically generate knowledge on

content teaching. In fact, the above research could be related to the issue of pedagogical content knowledge.

Shulman(1986, 1987) advocated concept of pedagogical content knowledge, which was defined as one form of content knowledge, and was the subject-matter knowledge for teaching. It included the forms of presenting science topics, analogies, elicitation, examples, explanation, and demonstration. In short, the teacher used different ways to transfer particular topics to particular level of students. Grossman's(1988) defined more specific of the four elements in pedagogical content knowledge which included: (1) teachers' beliefs on particular grade level, particular students, and particular topics; (2) identifying students' preconceptions on certain topics; (3) understanding particular curriculum including the connection between different subjects and within same subjects; (4) understanding the effective representing methods in teaching particular topics.

In describing the nature of pedagogical content knowledge, both Shulman (1987) and Kenny (1990) addressed it as the mixed and blended of content and pedagogy knowledge, which is a different kind of knowledge teachers held. However, other researchers (Cochran, 1991; Cochran, et al, 1993) using constructivist perspective in arguing with Shulman's compartment nature of pedagogical content knowledge, which was separated from pedagogy and content

knowledge. They believed that based on constructivist, teachers were active learners and tried to learn how students construct learning. Thus, pedagogical content knowledge should be dynamic, constant changing and evolving of pedagogy, and content knowledge. Cochran(1991) and Cochran, et al (1993) used pedagogical content knowing instead of pedagogical content knowledge. They defined pedagogical content knowing (PCKg) as teachers integrated knowledge of four domains of knowledge: subject matters, knowledge of pedagogy, knowledge of students, and knowledge of environmental contexts together. The more pedagogical content knowledge developed, the less distinguished within the other four domains of knowledge. Reynolds (1992) also defined PCK as the overlapping part of the three domains of knowledge: content knowledge, general principles of teaching and learning theories, and general subjects/ liberal arts.

Lederman with other researchers (Gess-Newsome & Lederman, 1993; Lederman & Latz, 1993; Lederman, Gess-Newsome, Latz, 1994) have done a series of research on investigating the nature and development of pre-service science teachers' knowledge structure of subject matter and pedagogy. They concluded that pedagogical content knowledge was not compartmentalized from content knowledge and pedagogical knowledge. These longitudinal studies done by Lederman with researchers were mainly based on

questionnaire and interview data. Thus really classroom observation were needed to illustrate the nature of pedagogical content knowledge.

In fact, the above argument of the nature of pedagogical content knowledge are from two perspectives one is from the micro aspect, which was concerned in the real classroom teaching, how the ways teachers present their content to their students (Shulman, 1986, 1987), another was from macro aspect, which was concerned with the degree of overlapping between two main domains of knowledge--pedagogy and content (Cochran, 1991; Cochran, et al, 1993; Lederman, Gess-Newsome, Latz, 1994). In this research, we applied Shulman, Lederman, and Cochran's ideas of PCK, and defined two aspects nature of pedagogical content knowledge, one is from the micro aspect, that is ways of representing content knowledge to students' level. Thus any forms of representing content knowledge were counted as pedagogical content knowledge. This perspective would be used in investigating the ways pre-service science teachers represent their content knowledge to students. Another way of looking pedagogical content knowledge is from macro aspect, that is the degree of integration of teachers' content knowledge and pedagogical knowledge. Therefore, the more integration teachers had in thinking of subject and pedagogy, the more their pedagogical content knowledge developed.

Purposes of this study are (1) to investigate the nature and development of content and pedagogy knowledge held by three pre-service chemistry teachers during one year of practicum course; (2) to explore the nature and development of pedagogical content knowledge of three pre-service chemistry teachers during one year practicum course; (3) to investigate the factors which influence the pre-service chemistry teachers' pedagogical content knowledge development.

Finding of this study will help science educators to reveal the nature and development of content, pedagogy, and pedagogical content knowledge held by pre-service teachers, to elucidate the impact of science teacher preparation program on their professional development, and to improve to the future science teacher preparation program.

Research Design

Method Because of the exploratory nature of the study, a qualitative method with case-study design (Bogdan & Biklen, 1992) was used which could provide more flexible ways and investigate in-depth view in answering research questions. The study was conducted in the practicum course offered by the chemistry department. Semi-structured interview were conducted to collect subjects' knowledge on chemistry and pedagogy from macro-aspect. Examples of the questions are follows:

1. When you think of "teaching", what would it be like ? (you can draw the diagram or just describe what you think of .)
2. Have you used the previous way in thinking of your teaching?
3. When you think of "chemistry" what will it be liked? What's the connection of chemistry with other disciplines?
4. Have you used the previous way in thinking of your chemistry?
5. In an ideal situation how will you teach physical science?
6. What do you expect your students learned from junior high school physical science course?
7. What kinds of change in terms of chemistry and pedagogy have you made ? What causes the changes?

During three pre-service chemistry teachers' two times micro-teaching and the two chemistry units they were taught during one-month field-based practicum experience, the researchers asked the following questions before and after their teaching performance. This part of data would answer subject's pedagogical content knowledge from micro-aspect. Examples of the questions are listed below:

Before teaching
1. Could you describe all the knowledge you have on this topic you are teaching?
2. Which part of the knowledge you presented above will you teach to your students?
3. How will you represent the knowledge you have to your students?
3. In this topic, which part will students have misconceptions on?
4. How will you teach the concepts which students' have learning difficulty(or misconceptions)?
5. What's your teaching goals in this topic?

After teaching
1. Does your knowledge on this topic has been changed? What cause the change?
2. How will you change on the topic you just taught?
3. What's your strength and weakness of your teaching performance?
4. If you need to teach next time what kinds of change

will you make?

Using semi-structured interview protocols helped researchers to collect similar data across different subjects, which also allowed us to have chances to go in-depth of collecting data from the subjects. Besides semi-structured interviews, some informal interviews data after each classroom observations were also collected to support and supply classroom observation and formal interviews data. Other sources of data included both classroom observations during two times micro-teaching experience and three times student teaching experience, and written documents, such as subjects' assignments for the practicum course, journals, lesson plans, etc.

Initially seven subjects' data were collected by four researchers. In this study three subjects' data were presented which were mainly collected by the first two authors. After transcribing all the interview data, each subject's data were analyzed separately by individual researchers. Then, the first author met individually with the other researchers to discuss and to gain consensus of each researcher's findings. If researchers hold different perceptions of the data then researchers would go back to re-analyze data and then discussed again to get agreement of the findings. After analyzing each case, the research team met together to compare and contrast findings among three cases and revised previous explanation in order to

capture the findings across three subjects.

Context of the study The practicum course was held for two semesters in the chemistry department for senior pre-service chemistry teachers. The instructor which was also the first author applied reflective teaching (Schon, 1986), and peer coaching methods into the course. Thus, each pre-service chemistry teacher has to practice two times 20 minutes micro-teaching lessons to their classmates, and also needed to analyze their teaching performance by themselves and by their peer coach. They needed not only to write lesson plan on the topic they taught, but also needed to critic their own lesson plan and thought of new ways in improving them after their teaching.

In the second semester, each pre-service chemistry teacher had to enroll in a junior high school and taught two classes of physical science to 8th and/or 9th graders for one-month. During one-month field-based practicum, each pre-service teacher had to write journal focused on reflecting their teaching performance, they also needed to video-taped and analyzed one-hour their one-hour classroom teaching. After they went back to university, the instructor spent time to discuss the problems they confronted during field-based practicum, introduced several ways in improving one's teaching performance, conducting science fair, and designing test items.

Subjects All pre-service chemistry teachers enrolled in

the practicum courses had to write assignment on their views on chemistry and pedagogy to the instructor in the beginning of the semester. Among them, seven subjects selected in this study were pre-service chemistry teachers who put a lot of effort in writing their assignments, good in expressing their ideas in verbal and written format, and were willing to participate in this one year long study. In this study, seven subjects were analyzed, only three subjects' data were reported because of their different perspectives on their pedagogy and content knowledge. The contrast views among these three subjects provided a rich data in answering the research questions.

Finding

Background of the subjects

Ah-Jan, Ah-Lin, and Ah-Sha were all seniors chemistry major seniors enrolled in a Normal University located in central of Taiwan. They were all in the age of 22 to 23 year old. Their GPA were in the top 15% of the class, especially Ah-lin, he has been the top one in the class for eight semesters in the university. In their class, half of students ' tuition were self-supported, for these students, they did not have obligation to teach junior high schools. Almost of all the self-supported students will continue their study in chemistry area. The other half of students were supported by government, thus they have to become junior high school teachers after

graduation.

Among them, Ah-Jan and Ah-Sha's tuition were self-supported. Ah-Jan's goal was to go abroad to earn doctoral degree in chemistry after her graduation. Ah-Sha had made a decision to become teacher ever since she was enrolled in this university, so she was looking for a teaching job after graduation. Ah-Lin was government-supported student, he knew he needed to be a junior high school teacher after graduation.

Ah-Jan was a vivid, enthusiastic, and creative girl. She liked laboratory work very much, so she has been joined a laboratory research team for two years. Although Ah-Jan did not plan to teach in high school, but she was very earnest in preparing all the materials and assignments for the pracitcum course. In preparing and reflecting her teaching, she liked to think of many ways such as examples or lab activities in transmitting concepts to her students.

Ah-Sha was a calm, conservative with motherhood personality. Among all of her classmates, she was the few ones acted very self-composed and sternest in teaching. Every time in interviewing her, most of her responses addressed on students' needs, motivation, moral and behaviors. Although Ah-Sha liked to though of many ways which might improve her teaching, but to the end, for the conservative and safe reason, she did not change very much.

Ah-Lin was a typical good and hard-working student, he was shy & rigorous. He liked to response things based on books' information. He was the one addressed subject-matter knowledge the most, however with few knowledge on students, which caused him many trouble in teaching to junior high school students.

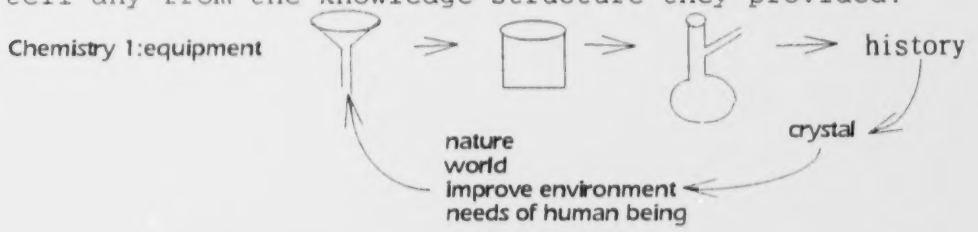
Findings and Discussion

Findings reported present the culmination of various subjects and analysis, and will be organized in answering the initial research questions.

The nature and development of pre-service chemistry's teachers' content knowledge

Interview and written responses indicated that pre-service teachers have not thought of and conceptualized the chemistry knowledge they have learned from college. Even thought the responses they provided varied from simply four fundamental chemistry courses--"physical, organic, analytical and inorganic chemistry", to list of additional topics and courses taken, and the preference they had at the university. All the preservice teachers were very surprised in answering questions on what do you think of chemistry. In the beginning, their responses were typically "I never thought of before", finally they tried to think of answers during interviews. Although, they listed the topic, courses they learned from university, which supported Lederman, Gess-Newsome, and

Latz (1994) data, however in posing subject's deeper knowledge on chemistry, the difference showed, which influenced by their preference in viewing the nature of chemistry. Among them, Ah-Jan is the only teacher, cared about the syntactic knowledge structure addressed by Shulman (1986, 1987). The other two teachers could not tell any from the knowledge structure they provided.



2:Chemistry & physics are not seperated, it is compensuled:
kinetic equilibrium; chemical phenomen appearance,
Can understand outside appearance,
physics analyzed the internal pants,
chemistry, mathematics → logical theory.
chemistry change history, direct history.
chemistry create literacy.

Fig1. A-Jan's Beginning C.K.

As mentioned before Ah-Jan likes laboratory activities very much, thus her description on chemistry had some components with laboratory equipment and her perceptions toward the nature of chemistry.

Ah-Lin was the only student tried very hard to explain the discipline structure from what he learned on college textbook. Even he put many effort, his responses were simplify added more topics he learned from the class.

In describing content knowledge on specific topic, pre-service chemistry teachers have more hierarchy-like knowledge structure on the topic they were teaching. These

knowledge structure were basically consisted of mainly the logical sequence of the concepts covered by the junior high school physical science textbooks, with some advanced concepts which covered by high school and college chemistry courses. Some evidence from their lesson plan are follows:

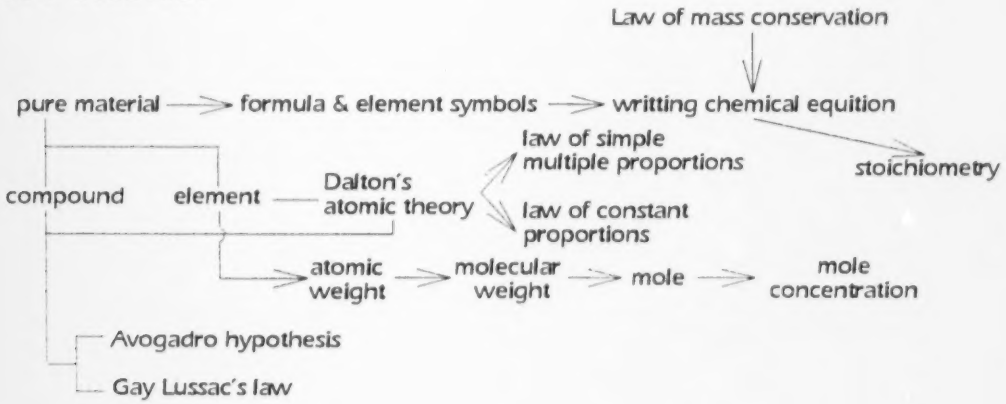


Fig2-1 Ah-Lin's C.K. on Ch.8

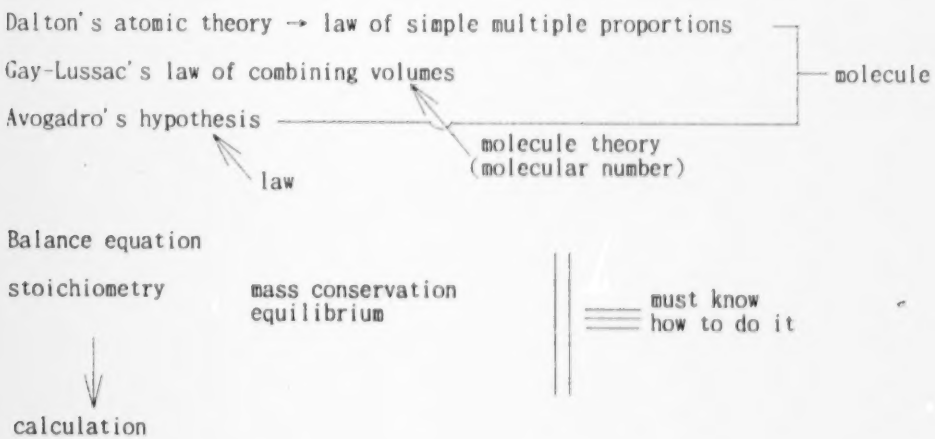


Fig2-2 Ah-Jan's C.K. on CH.8

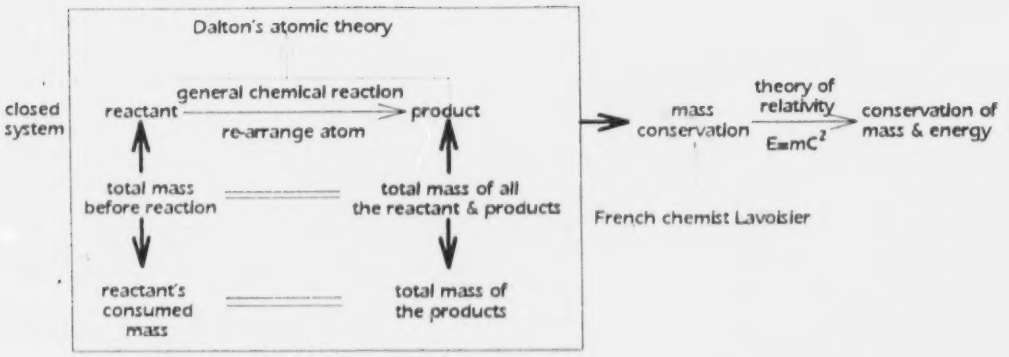


Fig2-3 Ah-Sha's C.K. on §7-5 mass of conservation

Finding supported Tuan, Chiang, and Lee(1993) study on a class of pre-service chemistry teachers' pre-active thinking which were mainly concerned the organization of science concepts.

As Ah-Jan and Ah-lin mentioned this kind of knowledge structure could help them and students to organize the content into meaningful and efficient way. Because most of the Taiwanese pre-service science teachers like very systematic way in presenting their content knowledge, and most of the students were educated in this way too.

Toward the end of year, the pre-service teachers' knowledge structure of chemistry became hierarchic-like, although the listed topics in the structure became simplify, but it connected more with other discipline area and daily life. They started to relate chemistry with the goal of junior high school physical science which address on the daily phenomena around students' living environment.

109 elements
- phtsical chemistry : finding some phisical principles from explore chemistry
- analytic chemistry : method, instrument
- organic chemistry : focus on carbon
- inorganic chemistry : other 108 elements except carbon

biochemistry, poiymerchemistry, 高分子化　學 .....
all belong to these four subjects.

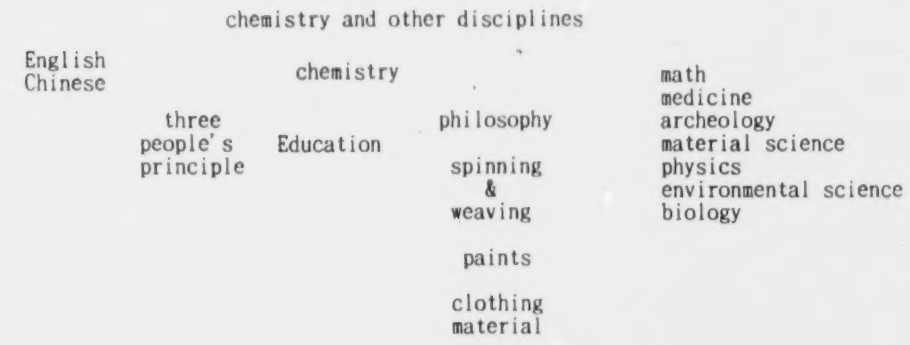


Fig3-1　Ah-Lin's final C.K.

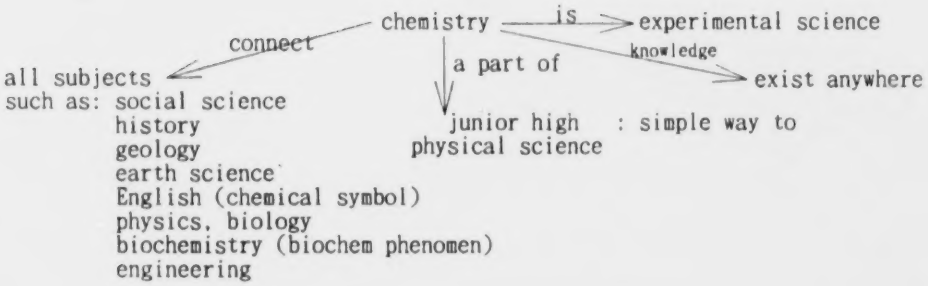


Fig3-2　Ah-Sha's final C.K.

The nature and development of preservice chemistry teachers' pedagogical knowledge

The nature of pre-service teachers' pedagogy knowledge are few principles with listing briefly on both teacher and students' role, which were mainly influenced. by the axiom of teaching in Chinese.

In responding what preservice teachers thought of pedagogy, all the subjects gave similar explanation of

"pedagogy is teaching and learning", which consisted all the activities and communication between students and teacher.

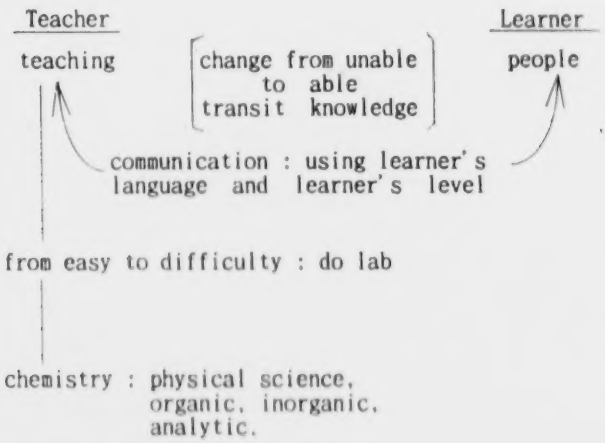

Teacher
Learner
teaching
change from unable to able transit knowledge
people
communication : using learner's language and learner's level
from easy to difficulty : do lab
chemistry : physical science, organic, inorganic, analytic.

Fig4-1 A-Sha's begining P.K. & C.K.

Teaching are ways to teach knowledge, experience to other people. In fact, in daily life teaching exist anytime and anywhere.Teaching established by people's communication, it can be transited by using language or written words to transit information and expree concepts.In teaching, we need to consider two aspects: teachers and learners. So, a successful teaching are related to these two kinds of people. (Ah-lin's beginning P.K.)

Pedagogy: Teaching and learning

Teaching and learning benefit each other no matter which level of students you are teaching, teachers need professional training.

Learning is a continuous work without stop. (Ah-Jan's beginning P.K.)

Examining similar explanation among subjects, we found pedagogy in Chinese consists of "teaching" and

"learning", thus, all the subjects' were very much like the definition on pedagogy. However, when researchers asked them to describe detail on their meaning about teaching and learning, they could not give very specific events.

Pedagogy knowledge stored in the preservice teachers' mind were more like abstract principle, instead of rigorous structured schema, these findings were unlike what Lederman, Gess-Newsome, & Latz (1994) finding on American pre-service science teachers. It seemed like American teachers hold more of concrete events on their pedagogy knowledge than Taiwanese pre-service teachers.

Toward the end of study, in asking pre-service teachers' knowledge on pedagogy, the subjects started to elaborate more and describe more specific events about teaching, they added more responsibility on teachers, and also many components related to students' learning characteristic and habit. Besides the above components, they also added issues related to school facility and environment, etc. These findings also supported by Lederman, Gess-Newsome, and Latz (1994) findings on their preservice science teachers' pedagogical knowledge development. Some evidence are as follows:

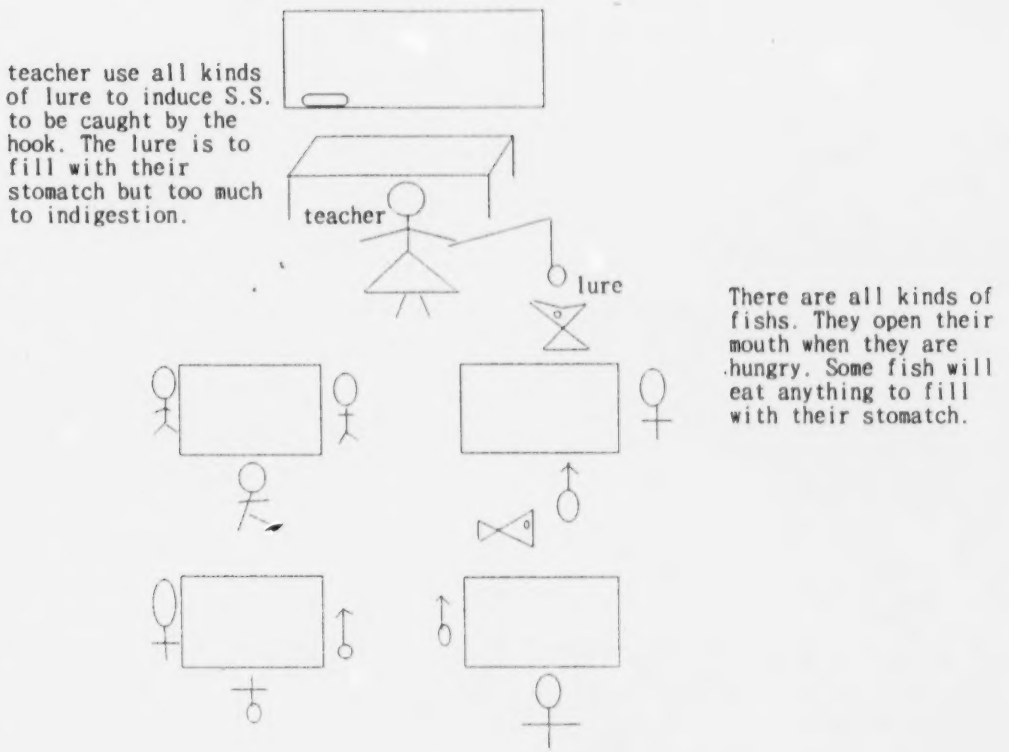

teacher use all kinds of lure to induce S.S. to be caught by the hook. The lure is to fill with their stomatch but too much to indigestion.
teacher
lure
There are all kinds of fishs. They open their mouth when they are hungry. Some fish will eat anything to fill with their stomatch.
Teacher need to pay attention in raising the fries, choose fishpond, adjust temperature, protect them.

Fig 5-1 Ah-Jan's final P.K.

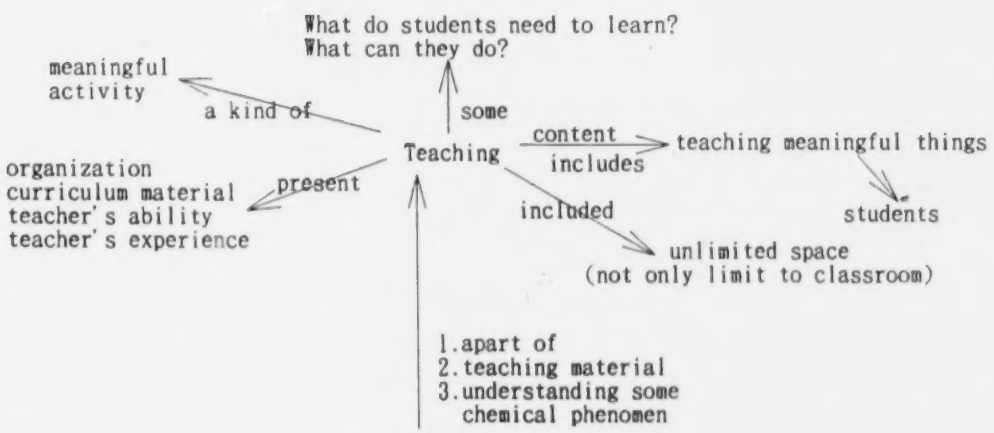


Fig5-2 Ah-Sha's final P.K.

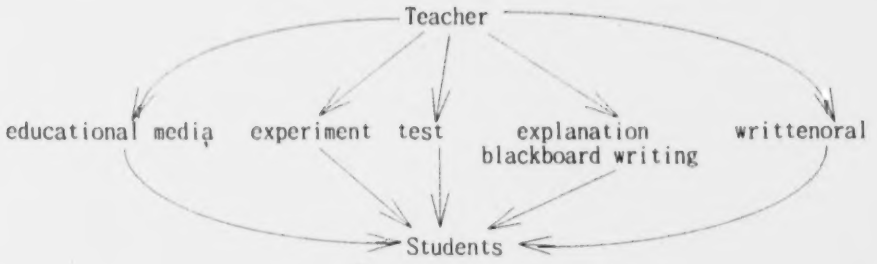


Fig5-3 Ah-Lin's final P.K.

The nature and development of pedagogical content knowledge

Pre-service chemistry teachers lacked of repertoire in representing science content to their pupils. Typical ways in presenting content were simply introducing the concepts, explaining the definition of concepts, applying concepts to daily life events and/or calculation problems. The difference among three subjects were Ah-lin used most of time in giving definition of the concepts to his students, both Ah-Jan and Ah-Sha liked to use daily life examples and/or analogies to explain concepts to students. Ah-Jan typically liked to use demonstration or conduct lab activities to facilitate students' understanding new concepts.

> *[Ah-Jan used lab activity to show students how copper was electroplated with nickel, and then explained to researcher] I showed them, then students would think whether they could used five, ten, or fifty dollars to electroplate, and to see see and to discuss the difference...*

The kinds of examples and analogies used during their teaching are listed:

> *Mole is the unit of atom, it is just like done is a unit of eggs or pencils*

Chemical reaction is rearrange atoms, but the total atoms and mass do not change. It is like a red pen and a black pen
red cap + black cap ---->black cap + red cap
red pen black pen red pen black pen

One important feature of pedagogy content knowledge defined by Shulman(1986) was teachers could identify and overcome students' misconceptions. However, finding of the study showed that these teachers do not aware of students' misconceptions, which also shown in Marks(1990) study. However, these pre-service teachers do aware of students' learning difficulty which was based on their previous learning experience, students' verbal and non-verbal responses in the class, and the test results. In Tuan(1994), Fong & Tuan(1993) studies, showed that pre-service chemistry teachers' used their learning experience as image to predict students' learning difficulty. Unfortunately, lacking of bountiful and substantial teaching repertoire, especially strategies on conceptual change teaching, these pre-service teachers could only use slow-paced repetition to re-teach their pupils. Westerman (1991) & Tuan (1994) also concluded that lacking of teaching repertoire in their schema which obstacle beginning teachers in finding new ways to improve their teaching performance.

For instance, they do not know how to calculate molecular weight of glucose, so I wrote down the method step by step,. For instance, in glucose, there are 6 C 12, 12

H1, used this method step by step to calculate molecular weight of glucose, then to calculate mole of glucose.

After reflection on their classroom teaching performance, pre-service chemistry teachers would address on how to motivate students' interested in learning, and the kinds of analogies and examples they could use in helping students understand concepts. Although during the study period, these preservice chemistry teachers did not change their teaching performance much, but these awareness could help them address the importance of pedagogical content knowledge.

As Cochran (1993), Lederman (1993), Reynolds(1990) pointed out, as a teacher overlaps one's content and pedagogy knowledge, the pedagogical content knowledge were developed. From the macro point of view, in the end of practicum course, the pre-service science teachers started to link the subject-matter knowledge and pedagogy knowledge together in thinking of science teaching.

Among the three subjects, Ah-Sha was the only one who thought of content was part of teaching, therefore, she linked chemistry and teaching in the beginning of the practicum course. The other two subjects-- Ah-lin and Ah-Jan, their responses related to the connection between pedagogy and chemistry were rare. But toward the end of study, when researchers asked their responses separately on chemistry and pedagogy, they started to aware these two

separately disciplines had some connection.

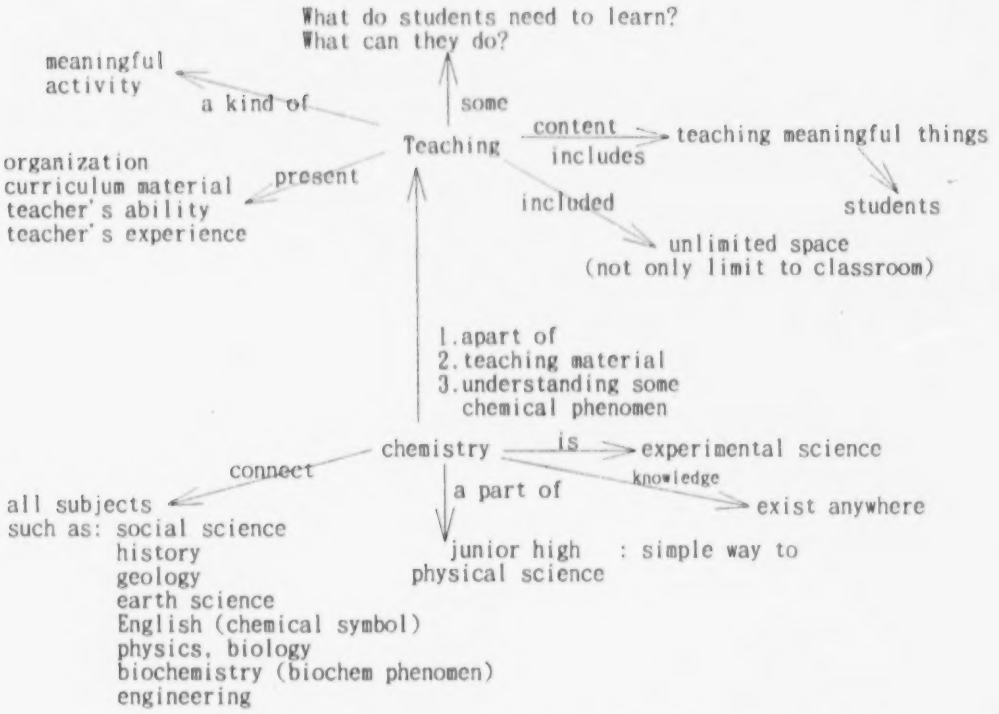


Fig6-1 Ah-Sha's final teaching & chemistry

Factors influenced pre-service chemistry teachers' pedagogical content knowledge development

Factors influenced pre-service chemistry teachers' pedagogical content knowledge development were "their ability and willingness in reflecting and improving their teaching experience influenced their pedagogical content knowledge development pace.

Subjects with strong reflection ability and devoted themselves to make change, developed pedagogical content knowledge better than the ones had weak reflection and

action ability.

Ah-Jan, Ah-lin and Ah-Sha were students liked to reflect on their teaching. Ah-Jan liked to put action in changing and trying out new ways of teaching, thus most of her informal interviews were addressed on her different teaching strategies, and how successful her teaching was. Her problem solving skills were also good, that she could find out the problem and tried to solve the teaching problem she confronted.

Ah-Sha was also good in identifying problems faced in the classroom, she also would talk many ways to solve the problem or to improve her teaching, but her conservative personality and unwilling to put action, made her keep the same old teaching strategies in her classroom teaching.

Ah-Lin always concentrated on his content knowledge, and blamed on students' laziness for not understanding. He did not know much about students' characteristic, and did not seem to care this issue. Only toward the end of the year, did he start to realize the simplicity of the content knowledge and the analogies were the ways to make students understand.

> *Researcher: What kind of change did you made during ng field-based practicum?*
> *Ah-Lin: I realized the importance of lab activities. I used to talk too much jargon for students to understand. This is not good for students. I hope I can use more*

vivid way in teaching, such as using demonstration or lab activities to impress them.

The real classroom context subjects involved during field-based practicum experience facilitate their pedagogical content knowledge development.

As mentioned before, these subjects needed to teach in two different contexts, one was in micro-teaching context and another was in really classroom setting. These subjects all mentioned that micro-teaching experience was a very "fake" situation where all their classmates played like junior high school students. These junior high school students were too much bright knowledge which made the situation very unreal. The subjects' reflection on micro-teaching performance were concentrated on their own performance, such as whether they spoke too fast or not, how were their hand writing. But in their real classroom teaching, these pre-service chemistry teachers' responses were all concentrated on students, such as students' responses, reactions, and motivation, which motivated pre-service chemistry teachers in findings alternative representation of content to their pupils. Thus, the dynamic interaction between teacher and students helped the pre-service chemistry teachers develop their pedagogical content knowledge.

Conclusion and Recommendations

Finding of the study illustrated the nature of the

pre-service chemistry teachers' content knowledge structure were few topics or experience related to the courses they took in college. Although, these chemistry major pre-service teachers have studied chemistry for four years, however, they did not really conceptualize what they have learned into understanding the topic they are teaching. In fact, they only applied fragment factual knowledge learned from college courses into explanation the topic they are teaching. Basically, they still relied heavily on the junior high school physical science textbooks. As Shulman (1986) advocated the importance of substantial and syntactic knowledge of subject discipline, these pre-service teachers need to learn conceptually on their chemistry discipline instead of simply memorized the irrelevant and fragment knowledge from all the content courses.

Toward the end of study, for the utilitarian point of view, these teachers have thought of the usefulness and purpose of subject-matter knowledge to their junior high school students during their interaction with students, their chemistry knowledge structure became simpler and simpler.

In their pedagogy knowledge structure, which mainly focused on the interpretation of "teaching" term in the beginning, toward the end of study, the pre-service chemistry teachers' pedagogy knowledge structure were more

elaborated, especially on the component of students. These might revealed the influence teachers had from the real classroom experience, which helped them to construct more and more elaborated knowledge on any aspect of teaching--both teacher and students. Few of educational courses and terms also have some influenced on these teachers' knowledge on pedagogy.

At the end of year, the pre-service chemistry teachers started to link pedagogy and content knowledge together in thinking of teaching, which based on Cochran et al (1993) , Reynolds (1987), & Lederman, Gess-Newsome, & Latz (1994) definition as pedagogical content knowledge development. But looking at the micro point view of the pedagogical content knowledge development, which suggested by Shulman(1986), these pre-service teachers still lacked of the various conceptual change teaching strategies, and coming out analogies and examples to represent concepts to their pupils.

Factors influenced these pre-service chemistry teachers' pedagogical content knowledge development were their weak reflection ability and deprived teaching repertoire, which restricted them in finding alternative ways in improving their classroom teaching. Other factor were the real classroom teaching experience, which helped them gain knowledge on students. Finally, pre-service chemistry teachers' preference also influenced how much

attention would the pre-service chemistry teachers' put on content, pedagogy or pedagogical content knowledge, and the direction of the changes would be. This finding has been supported by Gudmundsdottir(1990), who addressed the importance of teachers' value in influencing their pedagogical content knowledge development. This value issue needed to be addressed in the future.

Suggestions from what we have learned from these teachers are as follows:

(1) Science educators should encourage the pre-service science teachers to conceptualize the topics they need to teach. Such as what are the goals of the topic they are teaching, what the important concepts, and peripheral concepts related to the topic, and which concepts needed to be covered for the students.

(2) Science educators should provide opportunities for pre-service teachers with experienced teachers to discuss about the various ways in representing their understanding of the subject to the pupils, such as analogies, and examples; to discuss students' learning difficulty in particular topics.

(3) The science course instructors should address the importance of syntactical and substantial of the subject discipline to the pre-service teachers instead of simply request them to memorize meaningless facial knowledge.

(4) The pre-service teachers' reflect ability are the

factor which influence their pedagogical content knowledge development. Thus science educators should help pre-service teachers know how to reflect on their teaching performance.

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